Missouri Department of Natural Resources

Biological Assessment Report

Thurman Creek
Newton County, Missouri

2012 - 2013

Prepared for:
Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

Prepared by:
Missouri Department of Natural Resources
Division of Environmental Quality
Environmental Services Program
Water Quality Monitoring Section

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1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MDNR**) Water Protection Program (**WPP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a biological assessment of Thurman Creek. Thurman Creek is located in the Ozark/Neosho Ecological Drainage Unit (**EDU**), originating near the Jasper/Newton County line. Thurman Creek is designated as a Class P stream (Water Body Identification [**WBID**] 3243) in the Missouri Water Quality Standards (MDNR 2014) for three miles starting in Saginaw in Newton County to its confluence with Shoal Creek. Designated uses for Thurman Creek are "warm water aquatic life protection, human health/fish consumption, livestock and wildlife watering, and whole body contact recreation – category B" (MDNR 2014).

1.1 Study Area/Justification

Although Thurman Creek is on the 2012 impaired waters list and the proposed 2014 impaired waters list for *Escherichia coli*, the WPP requested the bioassessment due to concerns regarding contaminant metals from historic lead and zinc mining. According to the MDNR Hazardous Waste Program Web site, lead mining began in the Joplin area in the 1850s, and zinc mining began in the 1870s. The Joplin area quickly became prominent in the metals industry, and the production of lead and zinc from ores in the Joplin area peaked in 1916. Mining in the area ended in the late 1950s. After approximately 100 years of mining, the Joplin area contains hundreds of abandoned shaft and pit mines along with their associated chat and tailings piles. Many of the deposits were small, resulting in a large number of shallow pits with scattered chat and tailings piles. Because of the lack of efficiency associated with the extraction of metals from mining ores at the time, residual contaminant metals remain in these abandoned chat and tailings piles.

1.2 Objectives

1) Assess the biological (macroinvertebrate) integrity and water quality of Thurman Creek.
2) Determine the stream habitat quality of Thurman Creek.
3) Characterize contaminant metals in the surface water, fine sediment, and pore water of Thurman Creek.

1.3 Tasks

1) Conduct a biological assessment on Thurman Creek.
2) Conduct a stream habitat assessment at Thurman Creek to ensure comparability of aquatic habitats.
3) Collect water quality field measurements and surface water, fine sediment, and pore water samples at Thurman Creek.

1.4 Null Hypotheses

1) The macroinvertebrate community in Thurman Creek will not differ from the riffle/pool biological criteria for the Ozark/Neosho EDU.
2) The stream habitat assessment scores in Thurman Creek will not differ from Mikes Creek, a candidate riffle/pool biological criteria reference stream in the Ozark/Neosho EDU.

3) Physicochemical water quality in the surface water of Thurman Creek will meet the Water Quality Standards of Missouri (MDNR 2014).
4) Total metals in the pore water and fine sediment of Thurman Creek will not exceed consensus-based guidelines.

2.0 Methods

Mike Irwin of the Biological Assessment Unit, WQMS, ESP, Division of Environmental Quality (**DEQ)**, MDNR, conducted this study. Bioassessment, physicochemical, and fine sediment field work for the fall 2012 and spring 2013 sampling seasons was conducted by Brandy Bergthold, Ken Lister, and Carl Wakefield of the Biological Assessment Unit. Habitat assessments were conducted by Mike Irwin and Carl Wakefield. Pore water field work was completed by Ken Lister and Carl Wakefield.

2.1 Study Timing

Macroinvertebrate, discrete water quality, and sediment samples were collected once during the fall 2012 and spring 2013 sampling seasons. The habitat assessment for the Thurman Creek station was completed during the fall 2012 season. Habitat assessment of Mikes Creek was conducted in fall 2013. Pore water samples were collected in August 2013.

2.2 Station Descriptions

The study area and sampling location for the Thurman Creek bioassessment study are shown in Figure 1. One Thurman Creek station was surveyed for bioassessment, water quality, pore water, and fine sediment sampling.

2.2.1 Bioassessment Sampling Station

Thurman Creek – Newton County: Legal description was SW¼ Sec. 36, T. 27 N., R. 33 W. Geographic coordinates were UTM zone 15, 0368282 Easting, 4097408 Northing. The station was located downstream of Gateway Drive (US Business 71).

2.2.2 Candidate Reference Habitat Assessment Station

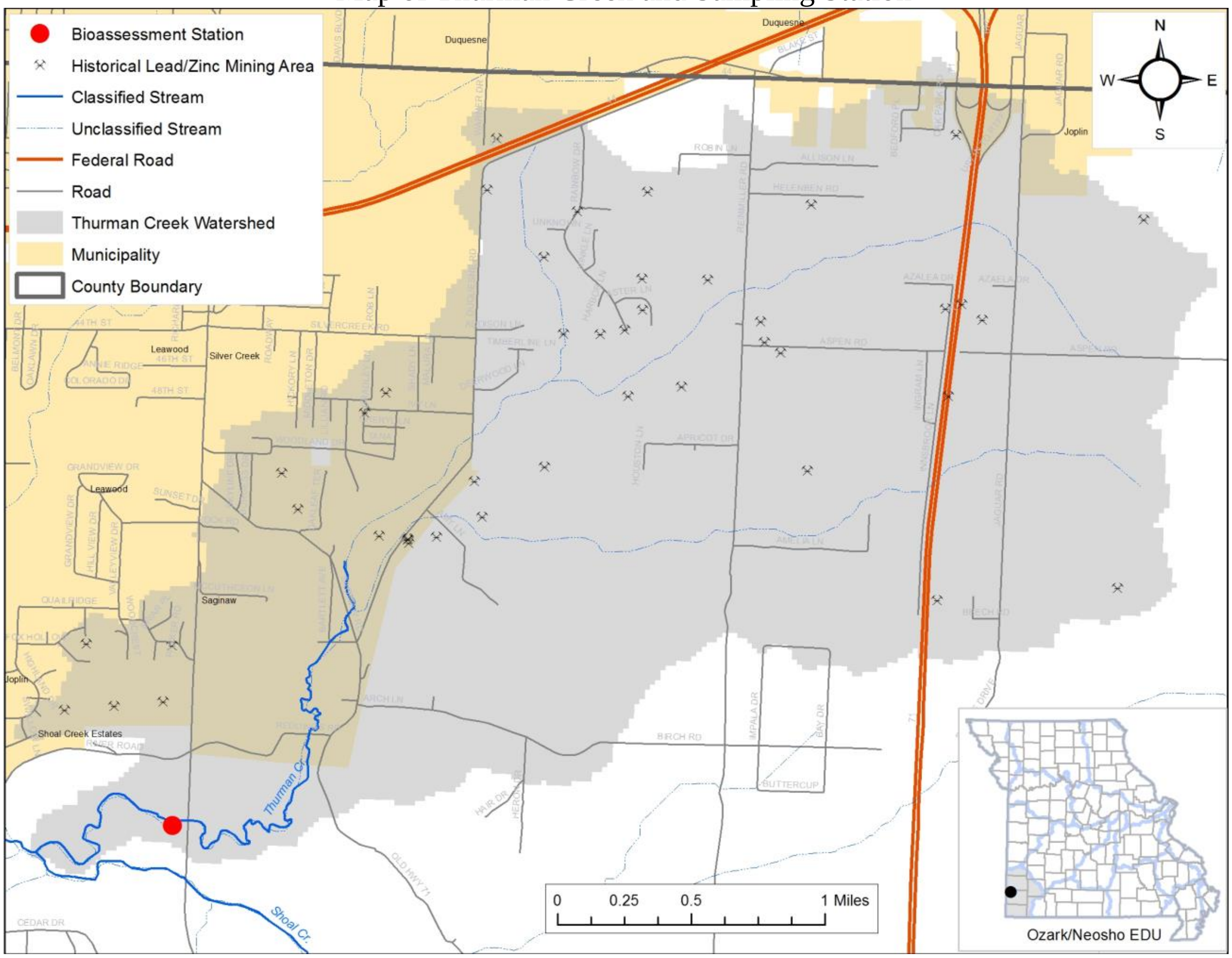
Mikes Creek – McDonald County: Legal description was SW¼ NW¼ Sec. 29, T. 23 N., R. 29 W. Geographic coordinates were UTM zone 15, 0402207 Easting, 4060345 Northing. The station was located downstream of Highway U.

2.3 Ecological Classification

The Thurman Creek watershed is located in the Ozark Highlands ecoregion. The aquatic ecological classification developed by the Missouri Resource Assessment Partnership (**MoRAP**) is a classification system that divides the aquatic resources of Missouri into distinct regions. It has seven levels of classification starting at large regions and then dividing them into smaller sub-regions (Sowa & Diamond 2006). The following are the seven levels of classification in hierarchical order: zone, subzone, region, aquatic subregions, EDU, Aquatic Ecological Systems (**AES**), and Valley Segment Types (**VST**). The levels of classification are based on biology, zoogeography, taxonomic composition, geology, soils, and groundwater connection. Some levels of the hierarchical system use geology and soils to classify, and other levels use biology

and taxonomic composition of aquatic communities. EDU and AES are the two levels of the classification system that will be assessed in detail for this study.

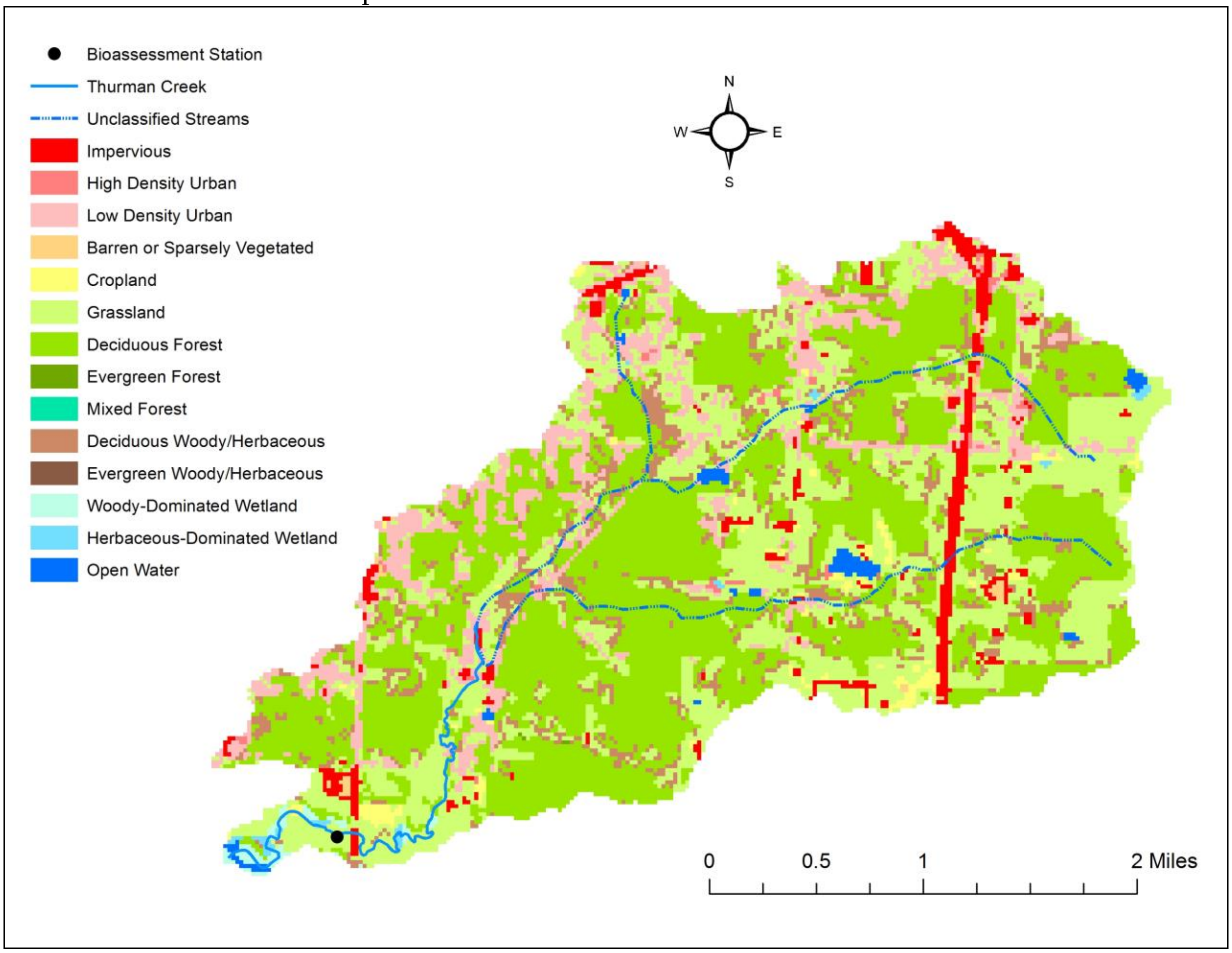
Figure 1
Map of Thurman Creek and Sampling Station



2.3.1 Ecological Drainage Unit

The EDU is level five of the classification hierarchy and is based on geographical variation of the taxonomic composition of the level four subregions. An EDU is a region in which aquatic biological communities and habitat conditions can be expected to be similar. Figure 2 is a map of the land cover within the Thurman Creek watershed. Table 1 shows the land cover percentages from the Thurman Creek watershed, the Ozark/Neosho EDU, and the 12-digit hydrologic unit codes (**HUC**) that contain biological reference streams (**BIOREF**) within the Ozark/Neosho EDU. Land use conditions were summarized from land cover geographic information system (**GIS**) files. Percent land cover data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the MoRAP (Sowa et al. 2004).

Figure 2
Map of Thurman Creek Land Use/Land Cover



2.3.2 Aquatic Ecological Systems

AES are level six of the classification hierarchy and classify aquatic systems into types based on geology, soils, landform, and groundwater influence. Thurman Creek is located in the Upper Spring River of the Neosho Aquatic Ecological Systems Type. According to Sowa and Diamond (2006):

> Local relief is generally less than 30 meters, but will occasionally approach 60 meters. Mississippian period cherty limestones underlie deep soils that formed in this weathered cherty limestone covered with loess. Surface soil textures consist of loams and silty loams with slow to moderate infiltration rates. Karst features are prominent, especially notable are the large number of springs and sinkholes that dot the AES-Type. Stream discharges are highest in the spring and lowest in the fall and flash floods are common after large rain events. Streams generally carry bed loads of cherty gravel and sand. Coldwater is an important ecological feature in this Type. Because springs are abundant and often large, they contribute to maintaining stream base flows. Groundwater is

usually abundant and of good quality. There are 101 headwater/creek springs and 15 main stem springs scattered throughout the Missouri portion of this AES-Type. This AES-Type contains two springs over 10 cubic feet per second (cfs). The median spring count is 14. The combined headwater and creek mean stream gradient is relatively low at 8.6 meters per kilometer. Historic vegetation was principally prairie with timber found along streams.

Table 1
Percent Land Use/Land Cover

Watershed/HUC12/EDU	Impervious	High Intensity Urban	Low Intensity Urban	Barren or Sparsely Vegetated	Cropland	Grassland	Deciduous Forest	Evergreen Forest	Deciduous Woody/Herbaceous	Woody-Dominated Wetland	Herbaceous-Dominated Wetland	Open Water
Thurman Creek	3.9	0.5	10.4	0.4	1.3	29.3	44.5	0	8.0	0.5	0.3	0.8
Ozark/Neosho EDU	2.6	0.2	1.9	0.6	15.2	52.8	20.3	0.1	4.8	0.9	0.2	0.5
Big Sugar Creek (110702080103)	1.0	0.0	0.1	0.8	0.9	29.3	52.8	1.0	13.8	0.1	0.0	0.2
Big Sugar Creek (110702080107)	0.6	0	0	0.7	0.6	28.2	56.3	0.2	12.9	0.2	0	0.3
Jones Creek (11070207070604)	2.4	0	0.3	0.2	6.9	69.0	16.5	0.1	3.7	0.6	0.2	0.2
Mikes Creek (110702080106)	0.4	0	0	0.6	0.5	17.6	73.0	0.2	7.5	0.2	0	0

2.4 Stream Habitat Assessment

A standardized assessment procedure was followed as described for riffle/pool (**RP**) habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (MDNR 2010a). Habitat assessments were conducted on Thurman Creek during September 2012 and a candidate biological reference stream location on Mikes Creek in September 2013. The Mikes Creek candidate biological reference was chosen for habitat comparison because it is more similar in size to Thurman Creek than the Big Sugar Creek, Jones Creek, or the downstream Mikes Creek biological reference stream reaches.

2.5 Biological Assessment

Biological assessments consist of macroinvertebrate collection and physicochemical sampling for two sample periods.

2.5.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (MDNR 2012a) for RP streams. Samples were collected from the following standard RP habitats: coarse substrate (**CS**); depositional substrate in non-flowing water (**NF**); and root mat (**RM**).

Macroinvertebrate data were analyzed using three methods. The first analysis was calculating the Macroinvertebrate Stream Condition Index (**MSCI**). The MSCI is calculated using the biological criteria for perennial/wadeable streams from the Ozark/Neosho EDU using the four general biological metrics found in the SMSBPP (MDNR 2012a). The four general biological metrics used and found in the SMSBPP are: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). The second analysis was an evaluation of macroinvertebrate community composition by percent composition of dominant macroinvertebrate groups. The third analysis was an evaluation of the predominance of taxa of varying BI ranges at the Thurman Creek station and collectively for biological reference streams within the Ozark/Neosho EDU. Taxa were divided into the following five BI tolerance value ranges in order of most sensitive to most tolerant: 0 to <2.5, 2.5 to 4.9, 5.0 to 7.4, 7.4 to 8.9, and >8.9. Percentages of total taxa were then calculated for each of these five sensitivity/tolerance ranges.

2.6 Physicochemical Data Collection and Analysis

2.6.1 *In situ* Water Quality Measurements

During each sampling period, *in situ* water quality measurements were collected at Thurman Creek. Field measurements included turbidity (**NTU**), pH (**su**), water temperature (**°C**), specific conductance (**µS/cm**), and dissolved oxygen (**mg/L**). For these measurements, the following Standard Operating Procedures (**SOP**) were used: turbidity, MDNR-ESP-012 (MDNR 2010b); pH, MDNR-ESP-100 (MDNR 2012b); water temperature, MDNR-ESP-101 (MDNR 2010c); specific conductance, MDNR-ESP-102 (MDNR 2010d); and dissolved oxygen, MDNR-ESP-103 (MDNR 2012c).

2.6.2 Water Chemistry

Grab samples of stream water were collected and returned for analyses to ESP's Chemical Analysis Section (**CAS**). Water quality samples from Thurman Creek were analyzed for non-filterable residue (**NFR**), sulfate (**SO_4**), chloride (**Cl**), total phosphorus (**TP**), ammonia-N (**NH_3-N**), nitrate+nitrite-N (**NO_3+NO_2-N**), total nitrogen (**TN**), hardness, and dissolved metals. Procedures outlined in Field Sheet and Chain-of-Custody Record, SOP MDNR-ESP-002 (MDNR 2010e) and Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations, SOP MDNR-ESP-001 (MDNR 2011) were followed when collecting water quality samples. NFR, Cl, TP, NH_3-N, NO_3+NO_2-N, TN, and hardness are reported in mg/L. For dissolved metals, magnesium (**Mg**) and calcium (**Ca**) are reported in mg/L, while barium (**Ba**), cadmium (**Cd**), cobalt (**Co**), copper (**Cu**), lead (**Pb**), nickel (**Ni**) and zinc (**Zn**) are reported in µg/L.

Stream velocity was measured at each station during the survey period using a Marsh-McBirney Flo-Mate™ Model 2000. Discharge was calculated per the methods in the SOP MDNR-ESP-113, Flow Measurement in Open Channels (MDNR 2013). Discharge is reported as cfs.

2.6.3 Fine Sediment Character

Fine sediment was characterized at each sampling station for Cd, Pb, and Zn. Each sample was a composite of one 2-ounce jar collected downstream of three separate riffles, yielding an approximate 6-ounce total composite. These composites were then dried and analyzed by CAS for total cadmium, lead, and zinc. Procedures outlined in Field Sheet and Chain-of-Custody Record, SOP MDNR-ESP-002 (MDNR 2010e), and Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations, SOP MDNR-ESP-001 (MDNR 2011), were followed when collecting fine sediment samples. Results are reported in mg/kg.

2.6.4 Pore Water

Peepers (Serbst et al. 2003; Brumbaugh et al. 2002, 2007) were used *in situ* to collect samples for substrate pore water dissolved metals analysis. Materials used to construct the peepers were donated by the USGS's Columbia Environmental Research Center (**CERC**) in Columbia, Missouri. Peepers were prepared and deployed as described in Brumbaugh et al. (2007). Peepers were deployed at Thurman Creek from August 1 to August 14, 2013. Three peepers were buried in the substrate to a depth of approximately two inches in areas near the head of riffles as described by Brumbaugh et al. (2007) and three were placed in pools. Pore water samples were analyzed for dissolved barium, cadmium, calcium, cobalt, copper, lead, nickel, and zinc. Results were compared to Missouri Water Quality Standards (MDNR 2014).

Three field blanks were prepared to test for sampling influences. Each field blank was taken to the field during deployment and retrieval. The field blanks were sealed in a container and placed in a cooler with ice for deployment and retrieval. Prior to deployment, the peepers were kept in ultra-pure water as described by Brumbaugh et al. (2007). During the deployment period, the field blanks were placed in a refrigerator with a constant temperature near 3°C. The field blank and test peepers were capped in the field at the conclusion of the sampling period. All samples were placed in separate plastic bags, placed on ice, and transported to CERC. The samples were diluted (1:1) with 1% HNO_3 and placed in a 100 ml Nalgene bottle. A bottle blank was prepared using 100 ml of 1% HNO_3. The pore water samples were analyzed by the MDNR CAS using applicable SOPs. Results values were multiplied by two in order to correct for the 1% HNO_3 dilution.

2.7 Data Analysis and Quality Control

The physicochemical data were examined by variable to determine whether Thurman Creek had violations of the Missouri Water Quality Standards (MDNR 2014). Values for total metals in fine sediment were measured against the consensus-based Probable Effects Concentrations (**PEC**) and the Sum Probable Effect Quotient for cadmium, lead, and zinc (**$\Sigma PEQ_{Cd,Pb,Zn}$**) (MacDonald et al. 2000). The PEC is the level of a contaminant above which harmful effects are likely to be observed. The dry-weight PECs for cadmium, lead, and zinc are 4.98 mg/kg, 128

mg/kg, and 459 mg/kg, respectively. $\Sigma PEQ_{Cd,Pb,Zn}$ values are a ratio of the sample values in mg/kg dry weight divided by the PEC value for each associated metal. The $\Sigma PEC\text{-}Q_{Cd,Pb,Zn}$ is calculated using the following equation:

$$(Cd/4.98) + (Pb/128) + (Zn/459)$$

Values greater than or equal to 7.92 are considered likely to be toxic to benthic macroinvertebrates in the Tri-State Mining District (MacDonald et al. 2009). Contaminant metals in pore water samples were compared to Missouri Water Quality Standards chronic metals criteria (MDNR 2014).

3.0 Results

3.1 Stream Habitat Assessment

Habitat assessment scores for the Thurman Creek and the Mikes Creek candidate biological reference reach are shown in Table 2. Data were collected in September 2012 on Thurman Creek and September 2013 on Mikes Creek with Mike Irwin and Carl Wakefield performing the scoring. SHAPP guidance states that stations scoring at least 75 percent of the total score of reference/control stations should support a similar biological community. The stream habitat total scores indicated that Thurman Creek should support a similar macroinvertebrate community compared to the Mikes Creek candidate biological reference stream reach. Habitat parameter categories range from I (optimal) to IV (poor). Habitat parameter scores are listed in parentheses and range from 0 to 20 except for vegetative protection and riparian zone categories, which range from 0 to 10.

Table 2
Predominant Category Habitat Values, Category Habitat Scores, and Total Habitat Scores from Stream Habitat Assessments for Thurman Creek and the Mikes Creek Biological Reference Stream Reach

Stream Habitat Parameters	Thurman Creek	Mikes Creek
SHAPP Date	9/6/2012	9/23/2013
Epifaunal Substrate/Available Cover	II (11)	III (9)
Embeddedness	I (16)	II (15)
Velocity/Depth Regime	II (11)	II (14)
Sediment Deposition	IV (3)	II (13)
Channel Flow Status	II (13)	III (8)
Channel Alteration	I (20)	I (20)
Riffle Quality	III (10)	III (9)
Bank Stability – Left Bank	II (6)	I (9)
Bank Stability – Right Bank	I (10)	I (10)
Vegetative Protection – Left Bank	IV (1)	IV (1)
Vegetative Protection – Right Bank	III (4)	IV (0)
Riparian Zone Width – Left Bank	IV (1)	I (10)
Riparian Zone Width – Right Bank	I (9)	I (9)
Total Habitat Score (% of BIOREF)	**115 (91)**	**127 (100)**

3.2 Macroinvertebrate Biological Assessment

3.2.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure

MSCI scores were calculated at Thurman Creek using the RP perennial/wadeable biological criteria for the Ozark/Neosho EDU. The MSCI scores for the fall 2012 and spring 2013 sampling seasons are shown in Table 3. Values shown in bold type are metric scores that are below the fully biologically supporting criteria.

Table 3
Fall 2012 and Spring 2013 Riffle/Pool Ozark/Neosho EDU Perennial/Wadeable Biological Criteria, Macroinvertebrate Stream Condition Index (MSCI) Scores, and Sustainability Categories at Thurman Creek

	TR (Score)	EPTT (Score)	BI (Score)	SDI (Score)	Total Score	Sustainability
Fall 2012						
Thurman Creek	82 (5)	**15 (3)**	**6.3 (3)**	3.53 (5)	16	Fully Biologically Supporting
Score of 5	>77	>24	<5.5	>2.97	--	Fully Biologically Supporting
Score of 3	77 - 39	24 - 12	5.5 - 7.7	2.97 - 1.49	--	Partially Biologically Supporting
Score of 1	<39	<12	>7.7	<1.49	--	Non-Biologically Supporting
Spring 2013						
Thurman Creek	84 (5)	**16 (3)**	**6.1 (3)**	3.30 (5)	16	Fully Biologically Supporting
Score of 5	>72	>27	<5.3	>3.01	--	Fully Biologically Supporting
Score of 3	72 - 36	27 - 13	5.3 - 7.7	3.01 - 1.51	--	Partially Biologically Supporting
Score of 1	<36	<13	>7.7	<1.51	--	Non-Biologically Supporting

In both seasons, the MSCI score placed Thurman Creek in the fully biologically supporting category. However, it is notable that EPTT and BI metrics for both seasons fell within the partially biologically supporting criteria category.

3.2.2 Percent EPTT and Dominant Macroinvertebrate Families

The percent of EPTT and the five dominant macroinvertebrate families at Thurman Creek for both seasons are presented in Table 4. Values in bold type represent the five dominant macroinvertebrate families and taxa for each station.

As can be expected by the EPTT metric falling in the partially biologically supporting range, percent EPTT was also low in abundance at Thurman Creek, particularly in the spring 2013 sample. Most notable regarding EPTT is the absence of Plecoptera. Elmidae, Chironomidae, and Tubificidae were dominant families in both sample seasons. Hyalellidae and Philopotamidae were dominant only in fall 2012, whereas Asellidae and Planariidae were dominant only in spring 2013 samples. The relative abundance of Philopotamidae in fall 2012 resulted in higher percent EPTT in fall 2012.

Table 4
Percent EPT and Dominant Macroinvertebrate Families at the Thurman Creek

Percent EPT taxa		
	Fall 2012	Spring 2013
% EPT	24.5	6.8
% Ephemeroptera	13.1	3.6
% Plecoptera	0	0
% Trichoptera	11.4	3.2
Percent Dominant Families (Top 5 in bold)		
	Fall 2012	Spring 2013
Elmidae	**16.6**	**7.1**
Chironomidae	**14.6**	**42.5**
Hyalellidae	**11.2**	3.7
Tubificidae	**9.1**	**5.4**
Philopotamidae	**6.1**	0.5
Asellidae	1.6	**17.6**
Planariidae	4.8	**5.6**

Another noteworthy trend is demonstrated by examining the percentages of Heptageniidae taxa among Thurman Creek, Ozark/Neosho EDU biological references, and the Mike's Creek candidate biological reference. A summary of this analysis is shown in Table 5, and the significance of reduced Heptageniidae taxa abundance will be discussed later in this report.

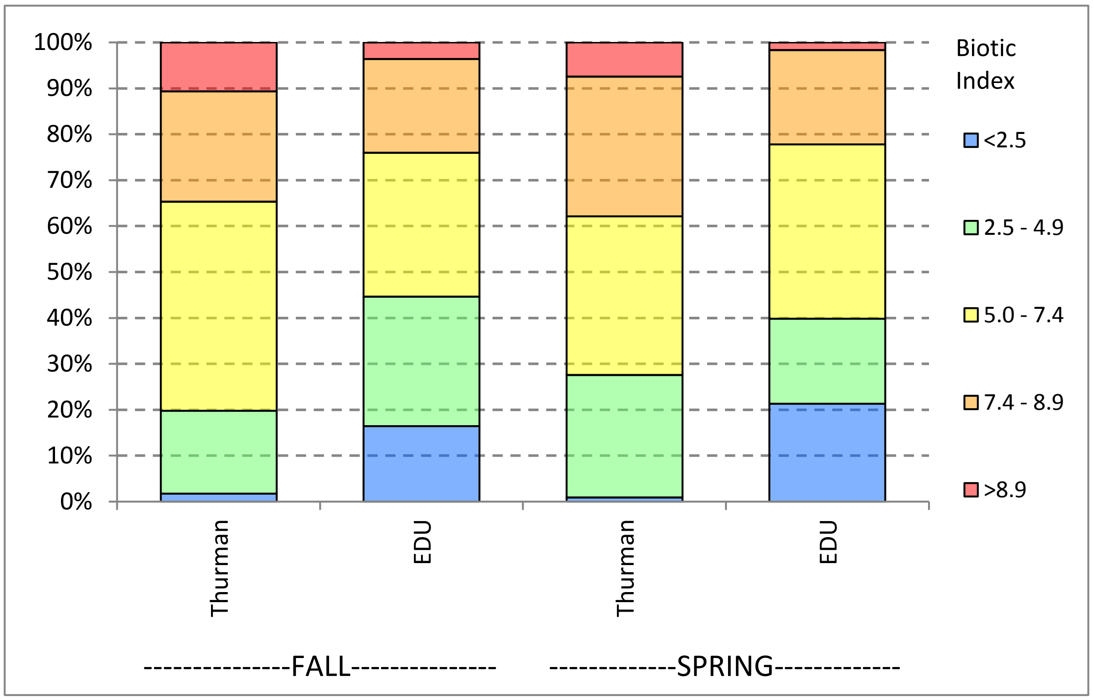
Table 5
Heptageniidae taxa as a percentage of total taxa for Thurman Creek and Ozark/Neosho Biological Reference Streams

Fall Samples	% Heptageniidae
Thurman Creek (n=1)	5.0
Big Sugar Creek BIOREF (n=3)	4.7 - 20.5
Jones Creek BIOREF (n=3)	6.2 - 13.5
Mikes Creek BIOREF (n=4)	4.4 - 9.9
Mikes Creek Candidate BIOREF (n=2)	5 - 7.8
Spring Samples	% Heptageniidae
Thurman Creek (n=1)	1.8
Big Sugar Creek BIOREF (n=3)	7.3 - 9.5
Jones Creek BIOREF (n=4)	3.4 - 7.1
Mikes Creek BIOREF (n=5)	9.7 - 17.9
Mikes Creek Candidate BIOREF (n=1)	4.0

3.2.3 Biotic Index

Since BI played a primary role in the reduction of MSCI scores, additional detail was generated for this metric. The percent of taxa by BI range is presented in Figure 3. Macroinvertebrate taxa that are sensitive to organic pollution were much less common in Thurman Creek than in the Ozark/Neosho EDU, while macroinvertebrate taxa that are tolerant to organic pollution were much more common in Thurman Creek than in the Ozark/Neosho EDU.

Figure 3
Percent of Taxa by Biotic Index Range



3.3 Physicochemical Data

3.3.1 Surface Water

Water samples and field measurements were collected during the fall 2012 and spring 2013 macroinvertebrate sampling periods at Thurman Creek. Results for field measurements and nutrients can be found in Table 6. Results for hardness and dissolved metals can be found in Table 7.

Table 6
Field Measurements and Nutrients in Thurman Creek Surface Water

Date/Time	DO mg/L	pH su	SC µS/cm	Temp °C	NFR mg/L	NTU mg/L	Flow cfs	NO_3+NO_2-N mg/L	NH_3-N mg/L	TN mg/L	TP mg/L	Cl- mg/L	SO_4 mg/L
9/20/12 10:00	6.82	7.0	391	17.0	7.00	6.28	1.59	0.87	0.034†	0.93	0.023†	11.6	9.91
4/2/13 12:15	11.34	8.3	309	10.0	20.0‡	4.84	5.18	1.38	0.052	1.58	0.027†	11.9	9.76

† Estimated Value ‡ Exceeded holding time

Table 7
Dissolved Metals and Hardness in Thurman Creek Surface Water

Date/Time	Ba µg/L	Cd µg/L	Co µg/L	Cu µg/L	Pb µg/L	Ni µg/L	Zn µg/L	Ca mg/L	Mg mg/L	Hardness mg/L
9/20/12 10:00	77.6	<0.1*	<1*	<0.5*	1.25	2.16	7.57	68.0	4.81	190
4/2/13 12:15	64.2	<0.1*	<1*	<0.5*	0.72†	1.29	46.3	54.9	3.36	151

* Below detectable limits † Estimated Value ‡ Exceeded holding time

In regards to field measurements and nutrients, there were no notable values, and parameters were within the applicable limits of Missouri's Water Quality Standards (MDNR 2014). Cadmium, cobalt, and copper concentrations were below detection limits. Barium, lead, nickel, and zinc levels were above detection limits for both seasons; however, none of the dissolved metals values were in violation of Missouri's Water Quality Standards (MDNR 2014).

3.3.2 Fine Sediment

Fine sediment samples were collected during both seasons. Total cadmium levels were not above PEC (MacDonald 2000) for either season. Total lead was above PEC for both seasons. Total zinc was above PEC for fall 2012 and just below PEC for spring 2013.
The $\Sigma PEQ_{Cd,Pb,Zn}$ for fall 2012 was above the published toxicity threshold (7.92) for the Tri-State Mining District (MacDonald 2009), while the spring 2013 sample was not. Results for fine sediment characterization can be found in Table 8. Values shown in bold are above published PEC or $\Sigma PEQ_{Cd,Pb,Zn}$ toxicity thresholds.

Table 8
Total Metals Character in Thurman Creek Fine Sediment

	Fall 2012	Spring 2013	PEC mg/kg
Cadmium mg/kg	4.48	2.42	4.98
Lead mg/kg	**829**	**204**	128
Zinc mg/kg	**1080**	456	459
$\Sigma PEQ_{Cd,Pb,Zn}$	**9.7**	3.1	

3.3.3 Pore Water

Pore water samples provide additional insight on contaminant metals. The bottle blank was below detection limits for all tested metals, and the field blanks all were below detection limits for all tested metals with the exception of zinc. According to CERC's William Brumbaugh (personal communication 01/15/2014), zinc contamination in the field blanks is likely a by-product of the plastic production process. Regardless of the reason, the presence of zinc contamination in the field blanks invalidates the use of zinc sample values. Results for pore water characterization can be found in Table 9. One of the peepers that was placed in a pool was not found; therefore, only two of three non-flow samples are shown in Table 9. Values shown in bold are above Missouri's Water Quality Standards (MDNR 2014), and zinc values have been omitted.

Table 9
Dissolved Metals and Hardness for Thurman Creek Pore Water

Parameter / Station Habitat Rep	Ba µg/L	Cd µg/L	Ca µg/L	Co µg/L	Cu µg/L	Fe µg/L	Pb µg/L	Mg µg/L	Mn µg/L	Ni µg/L	Hardness as $CaCO_3$ µg/L
Thurman Creek CS1	81.4	**0.44**	63.4	<1	<0.50	208	**33.8**	3.88	60.4	1.74	174
Thurman Creek CS2	85.6	<0.10	68	<1	<0.50	7.76	1.06	4.08	23.2	1.46	187
Thurman Creek CS3	110	<0.10	63.2	<1	<0.50	238	<0.50	3.78	2260	2.06	173
Thurman Creek NF2	72.6	<0.10	63.8	<1	<0.50	4.44	<0.50	3.9	9.08	<0.50	175
Thurman Creek NF3	98.6	<0.10	60	<1	<0.50	**6860**	<0.50	3.44	2780	<0.50	164

4.0 Discussion

A habitat assessment was not completed for a biological reference stream in the same EDU; however, the high quality of habitat found in the Mikes Creek candidate biological reference should be sufficient for habitat assessment comparisons in this study. Stream habitat total scores indicated that Thurman Creek should support a macroinvertebrate community similar to the reference conditions in the Ozark/Neosho EDU. Considering that the MSCI score is categorized as fully biologically supporting, this appears to be the case.

Although the Thurman Creek MSCI score was 16 for both seasons, there is evidence that cadmium, lead, and zinc occur in Thurman Creek sediment at concentrations likely to cause toxicity in benthic macroinvertebrates. Metals can affect aquatic organisms in water, in sediment, or in the food chain (Rainbow 1996; Maret et al. 2003). Maret et al. (2003) found that some Ephemeroptera taxa are significantly lower in number at streams contaminated by metals versus biological reference streams. Reduced EPTT and increased BI values provide some evidence of possible metals contamination. In particular, low abundance of Heptageniidae is an indicator of metals pollution (Clements et al. 1988, Clements et al. 2000) and these mayflies were much less abundant at Thurman Creek than biological reference streams within the Ozark/Neosho EDU. With respect to expected abundance of Heptageniidae, Thurman Creek Heptageniidae numbers were below or at the bottom of the expected range in both fall 2012 and spring 2013 samples when compared to biological reference streams and the Mikes Creek candidate reference site.

Although there were no violations of Missouri's Water Quality Standards (MDNR 2014) in Thurman Creek surface water samples, there was physicochemical evidence of potential toxicity to benthic macroinvertebrates in fine sediment and pore water samples. Lead values in fine sediment were above PEC in fall 2012 and spring 2013 samples. Zinc values in fine sediment were above PEC in the fall 2012 sample and just below PEC for the spring 2013 sample. According to the toxicity threshold associated with the $\Sigma PEC\text{-}Q_{Cd,Pb,Zn}$ calculation, the fine sediment sample from fall 2012 was likely to be toxic to benthic macroinvertebrates. Additionally, pore water from one coarse substrate sample violated Missouri Water Quality Standards criteria for cadmium and lead, and pore water from one non-flow sample violated Missouri Water Quality Standards criteria for iron. According to CERC's William Brumbaugh

(personal communication 12/04/2013), elevated iron concentrations are an indicator of anoxic pore water conditions, and this is especially likely in non-flow habitats. Since the intent of pore water sampling is to measure the biological availability of contaminant metals, anoxic pore water samples might not be valid; however, it is also important to note that no attempt was made to determine pore water dissolved oxygen levels. There is no evidence that anoxic conditions were a factor in any of the coarse substrate samples.

5.0 Conclusions

The first null hypothesis stated that the macroinvertebrate community in Thurman Creek will not differ from the RP biological criteria for the Ozark/Neosho EDU. The MSCI scores for Thurman Creek were fully biologically supporting for both seasons; therefore, the first null hypothesis is accepted.

The second null hypothesis stated that stream habitat assessment scores in Thurman Creek will not differ from Mikes Creek, a candidate RP biological criteria reference stream in the Ozark/Neosho EDU. The SHAPP score for Thurman Creek was 91 percent of the Mikes Creek candidate biological reference stream; therefore, the second null hypothesis is accepted.

The third null hypothesis stated that physicochemical water quality in the surface water of Thurman Creek will meet the Water Quality Standards of Missouri (MDNR 2014). No acute or chronic violations were discovered in surface water samples; therefore, the third null hypothesis is accepted.

The fourth null hypothesis stated total metals in the pore water and fine sediment of Thurman Creek will not exceed consensus-based guidelines. Fine sediment PECs for lead and zinc were exceeded in both seasons, and the ΣPEC-$Q_{Cd,Pb,Zn}$ threshold was exceeded in the fall 2012 fine sediment sample. Additionally, pore water from one coarse substrate sample exceeded Missouri’s Water Quality Standards (MDNR 2014) chronic criteria for cadmium and lead. Therefore, the fourth hypothesis is rejected.

Although the MSCI scores for each season are fully biologically supporting, reduced BI scores and Ephemeroptera/Heptageniidae abundance combined with a high likelihood of toxicity from contaminant metals in fine sediment and pore water suggest that abandoned lead and zinc mines are a valid concern in the Thurman Creek watershed.

6.0 Recommendations

- Studies that identify levels of dissolved metals bioaccumulated in taxa should be conducted periodically.

- Studies to determine specific macroinvertebrate/metal sensitivities, if possible, would be very helpful.

- Development of metrics and criteria specific to contaminant metals would provide valuable insight.

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Submitted by: ______________________________

Michael D. Irwin
Environmental Specialist
Water Quality Monitoring Section
Environmental Services Program

Date: ______________________________

Approved by: ______________________________

Alan Reinkemeyer
Director
Environmental Services Program

AR:mit

c: Trish Rielly, QAPP Project Manager, WPP
Cindy Davies, Director, Southwest Regional Office

Appendix A

Thurman Creek Macroinvertebrate Taxa Lists

(16 pages)

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [120101], Station #1, Sample Date: 9/20/2012 10:45:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	5	5	1
AMPHIPODA			
Crangonyx	3		21
Gammarus	11	2	3
Hyalella azteca	2	10	137
ARHYNCHOBDELLIDA			
Erpobdellidae	4	1	1
BASOMMATOPHORA			
Ancylidae	1	16	1
Helisoma			1
Menetus		3	1
BRANCHIOBDELLIDA			
Branchiobdellida		7	1
COLEOPTERA			
Dubiraphia	4	27	41
Ectopria nervosa	1	1	1
Macronychus glabratus			1
Optioservus sandersoni	82		
Psephenus herricki	42		1
Stenelmis	41		24
DECAPODA			
Orconectes neglectus	-99	1	1
DIPTERA			
Ablabesmyia		4	3
Ceratopogoninae	1	7	2
Chironomus	1	4	
Cladopelma		5	
Corynoneura	1		
Cryptochironomus	1	2	
Cryptotendipes		3	
Dicrotendipes		2	
Forcipomyiinae			1
Hemerodromia	1		
Hexatoma	-99		
Larsia	1		
Micropsectra			1
Microtendipes	4	1	1
Nanocladius		2	2
Nilotanypus	8		2
Parachironomus			1

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [120101], Station #1, Sample Date: 9/20/2012 10:45:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Parametriocnemus	1		
Paratanytarsus			2
Paratendipes	16	26	6
Polypedilum convictum	13		2
Polypedilum illinoense grp	2		
Polypedilum scalaenum grp	5		
Procladius		5	
Rheotanytarsus	3		8
Stempellinella	3		1
Tabanidae	1	1	
Tanypus		1	
Tanytarsus	2	21	2
Thienemanniella	4		1
Thienemannimyia grp.	14		6
EPHEMEROPTERA			
Baetidae	8		
Baetis	52		3
Caenis latipennis	4	12	3
Diphetor	9		
Hexagenia		2	
Isonychia bicolor	5		
Leptophlebiidae	4		1
Maccaffertium mediopunctatum	1		
Stenacron	41	22	2
Tricorythodes	3		1
HEMIPTERA			
Corixidae		13	
ISOPODA			
Lirceus	9		13
LUMBRICINA			
Lumbricina	5		
LUMBRICULIDA			
Lumbriculidae			4
MEGALOPTERA			
Corydalus	-99		1
Sialis		-99	
NEOTAENIOGLOSSA			
Elimia	8		2
Hydrobiidae		8	
ODONATA			
Argia	2		3
Basiaeschna janata			-99

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [120101], Station #1, Sample Date: 9/20/2012 10:45:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Calopterygidae	1		1
Enallagma		-99	1
Gomphidae	1		
TRICHOPTERA			
Cheumatopsyche	54		5
Chimarra	74		7
Helicopsyche	8	1	
Hydroptilidae		1	
Polycentropus			1
TRICLADIDA			
Planariidae	54		10
TUBIFICIDA			
Aulodrilus		2	
Limnodrilus cervix		1	
Limnodrilus hoffmeisteri		7	
Quistradrilus multisetosus	5	27	5
Tubificidae	28	39	7
VENEROIDA			
Pisidiidae	8	13	6

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [131905], Station #1, Sample Date: 4/2/2013 12:40:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	1	2	
AMPHIPODA			
Crangonyx		5	2
Gammarus	21		1
Hyalella azteca		2	44
ARHYNCHOBDELLIDA			
Erpobdellidae	-99	1	
BASOMMATOPHORA			
Ancylidae	1	6	1
Menetus			2
Physella			4
BRANCHIOBDELLIDA			
Branchiobdellida	1		
COLEOPTERA			
Dubiraphia	1	6	11
Dytiscidae		6	
Optioservus sandersoni	29		
Psephenus herricki	10	1	
Stenelmis	32		9
DECAPODA			
Orconectes neglectus	-99	-99	-99
DIPTERA			
Ablabesmyia		4	
Brillia			1
Cardiocladius	1		
Ceratopogoninae	1	2	1
Chironomidae			1
Cladopelma		9	
Cladotanytarsus		11	
Corynoneura			2
Cricotopus bicinctus			1
Cricotopus/Orthocladius	8	3	7
Cryptochironomus		3	
Cryptotendipes		37	
Dicrotendipes		7	4
Eukiefferiella	15		8
Hexatoma	-99		
Hydrobaenus		2	1
Micropsectra	2	2	4
Nanocladius			6

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [131905], Station #1, Sample Date: 4/2/2013 12:40:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Paralauterborniella		4	
Parametriocnemus	6	1	4
Paratanytarsus		2	2
Paratendipes	1	54	2
Polypedilum convictum	19		4
Polypedilum halterale grp		2	
Polypedilum illinoense grp	2		1
Polypedilum scalaenum grp	2		
Procladius		6	
Rheotanytarsus	6	3	7
Simulium	11		12
Stempellinella	2		2
Tabanus	-99		
Tanytarsus	2	41	6
Thienemanniella	2		7
Thienemannimyia grp.	10		3
Tvetenia bavarica grp	74		108
Zavrelimyia		1	
EPHEMEROPTERA			
Acentrella	1		
Acerpenna	3		
Baetis	2		
Caenis latipennis		3	1
Diphetor	9		2
Hexagenia limbata		-99	
Isonychia bicolor	-99		
Stenacron	18	5	
Tricorythodes	1		
ISOPODA			
Lirceus	216	2	
LUMBRICINA			
Lumbricina	1		
LUMBRICULIDA			
Lumbriculidae	1		1
MEGALOPTERA			
Corydalus	1		
Sialis		-99	
NEOTAENIOGLOSSA			
Elimia	18		1
ODONATA			
Argia			1
Boyeria			-99

Aquid Invertebrate Database Bench Sheet Report
Thurman Cr [131905], Station #1, Sample Date: 4/2/2013 12:40:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Calopteryx			2
Enallagma			1
TRICHOPTERA			
Cheumatopsyche	7		21
Chimarra	6		1
Helicopsyche	3		
Hydroptila			1
Polycentropus		-99	
Pycnopsyche	-99		-99
Triaenodes			1
TRICLADIDA			
Planariidae	64		6
TUBIFICIDA			
Limnodrilus claparedianus		2	
Limnodrilus hoffmeisteri		4	
Quistradrilus multisetosus		2	
Tubificidae	8	47	4
VENEROIDA			
Corbicula			-99
Pisidiidae	12		5